Does the Universe Need God?

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"In the beginning, God created the heavens and the earth."

In many religious traditions, one of the standard roles of the deity has been to create the universe. The first line of the Bible, Genesis 1:1, is a plain statement of this role. Much has happened, both in our scientific understanding of the universe and in the development of theology, since that line was first written. It's worth examining what those developments imply for the relationship between God and cosmology.

In some ways of thinking about God, there's no relationship at all; a conception of divinity that is sufficiently ineffable and transcendent may be completely separate from the workings of the physical world. For the purposes of this essay, however, we will limit ourselves to versions of God that play some role in explaining the world we see. In addition to the role of creator, God may also be invoked as that which sustains the world and allows it to exist, or more practically as an explanation for some of the specific contingent properties of the universe we observe.

Each of these possibilities necessarily leads to an engagement with science. Modern cosmology attempts to come up with the most powerful and economical possible understanding of the universe that is consistent with observational data. It's certainly conceivable that the methods of science could lead us to a self-contained picture of the universe that doesn't involve God in any way. If so, would we be correct to conclude that cosmology has undermined the reasons for believing in God, or at least a certain kind of reason?

This is not an open-and-shut question. We are not faced with a matter of judging the merits of a mature and compelling scientific theory, since we don't yet have such a theory. Rather, we are trying to predict the future: will there ever be a time when a conventional scientific model provides a complete understanding of the origin of the universe? Or, alternatively, do we already know enough to conclude that God definitely helps us explain the universe we see, in ways that a non-theistic approach can never hope to match?

Most modern cosmologists are convinced that conventional scientific progress will ultimately result in a self-contained understanding of the origin and evolution of the universe, without the need to invoke God or any other supernatural involvement.[1] This conviction necessarily falls short of a proof, but it is backed up by good reasons. While we don't have the final answers, I will attempt to explain the rationale behind the belief that science will ultimately understand the universe without involving God in any way.

The Universe We Know

A century ago, we knew essentially none of what are now considered the basic facts of cosmology. This situation changed rapidly, first on the theoretical front in the 1910's, then on the observational front in the 1920's.

Cosmology studies the universe on the largest scales, and over large scales the most important force of nature is gravity. Our modern understanding of gravity is the theory of general relativity, proposed by Einstein in 1915. The key insight in this theory is the idea that space and time can be curved and have a dynamical life of their own, changing in response to matter and energy. As early as 1917, Einstein applied his new theory to cosmology, taking as an assumption something we still believe is true: that on the largest scales, matter in the universe (or at least our observable part of it) is uniform through

space. He also assumed, consistent with the apparent implication of observations at the time, that the universe was static. To his surprise, Einstein found that general relativity implied that any uniform universe would necessarily be non-static – either expanding or contracting. In response he suggested modifying his theory by adding a new parameter called the "cosmological constant," which acted to push against the tendency of matter to contract together. With that modification, Einstein was able to find a static (but unstable) solution if the cosmological constant were chosen precisely to balance against the attraction of matter on large scales.

This discussion became somewhat academic when Edwin Hubble and Milton Humason announced in 1929 that the universe is expanding: distant galaxies are receding from us at speeds that are proportional to their distance. It had only been in 1924 that Hubble had established that the spiral nebulae, which many thought were clouds within our own galaxy, were separate galaxies in their own right, demonstrating the true vastness of the universe. The collection of stars we live in, the Milky Way galaxy, contains something over 100 billion stars, and there are over 100 billion such galaxies within the observable universe.

If the universe is expanding now, it was smaller in the past. (More properly, galaxies were closer together and the universe was more dense; it's possible that space is actually infinite in extent.) Using the rules provided by general relativity, and some assumptions about the types of matter and energy that pervade the universe, we can play the movie backwards in time to reconstruct the past history of our universe. Eventually – about 13.7 billion years ago, according to our best current estimates – we reach a moment of infinite density and spacetime curvature. This singularity is known as the "Big Bang." Confusingly, the phrase "Big Bang model" refers to the entire history of the expanding universe that began in a hot, dense state, the broad outlines of which are established beyond reasonable doubt. In contrast, the "Big Bang event" is not really an event at all, but a placeholder for our lack of complete understanding.

While we don't claim to understand the absolute beginning of the universe, by the time one second has elapsed we enter the realm of empirical testability. That's the era of primordial nucleosynthesis, when protons and neutrons were being converted into helium and other light elements. The theory of nucleosynthesis makes precise predictions for the relative abundance of these elements, which have passed observational muster with flying colors, providing impressive evidence in favor of the Big Bang model. Another important test comes from the cosmic microwave background (CMB), the relic radiation left over from the moment the primordial plasma cooled off and became transparent, about 380,000 years after the Big Bang. Together, observations of primordial element abundances and the CMB provide not only evidence in favor of the basic cosmological picture, but stringent constraints on the parameters describing the composition of our universe.

One implication of these data is that only about 4% of the total energy of the current universe is in the form of "ordinary matter" – the atoms and molecules consisting of protons, neutrons, and electrons, as well as photons and neutrinos and all the other known elementary particles. Another 23% of the universe is "dark matter" – a completely new kind of particle, as yet undiscovered here on Earth. In addition to constraints from nucleosynthesis and the CMB, strong evidence for dark matter comes from the dynamics of galaxies, clusters of galaxies, and large-scale structure in the universe (see Komatsu et al. 2001).

This leaves us with 73% of the universe in an even more mysterious form – "dark energy." Once the expansion of the universe was discovered, Einstein's original motivation for introducing the cosmological constant evaporated. But the idea didn't go away, and physicists later realized that this parameter had a very natural interpretation – the energy

density of empty space, or "vacuum energy" for short. In 1998 two groups of astronomers made a surprising discovery: the universe is not only expanding, but accelerating – distant galaxies are moving away from us faster and faster over time (Riess et al. 1998, Perlmutter et al. 1999). This is contrary to our expectation that the gravitational pull between galaxies should slow the expansion down. The most straightforward explanation for this acceleration is to posit dark energy – a smooth, persistent form of energy that isn't localized into particles, but is spread throughout space. Vacuum energy, or Einstein's cosmological constant, is the simplest candidate for dark energy; it features a density that is strictly constant, unchanging through space or time. But more complicated models are possible, and cosmologists are currently working hard to test the hypothesis that the dark energy density is truly a constant. If it is, we can predict the future of the universe – it will expand forever, gradually cooling and diluting away until nothing is left but empty space.

While the Big Bang model – the picture of a universe expanding from a hot, dense state over the course of billions of years – is firmly established, the Big Bang itself – the hypothetical singular moment of infinite density at the very beginning – remains mysterious. Cosmologists sometimes talk about the Big Bang, especially in popular-level presentations, in ways that convey more certainty than is really warranted, so it is worth our time to separate what we know from what we may guess.

The success of primordial nucleosynthesis gives us confidence that we understand what the universe was doing about one second after the Big Bang, but anything before that is necessarily speculative. Even the formulation "one second after the Big Bang" should really be interpreted as "one second after what would be the moment of infinite curvature in the most straightforward extrapolation to earlier times." But there are different degrees of speculation.

From one second back to about 10^{-43} seconds, we expect the *kinds* of physics we understand – general relativity and quantum field theory – to be applicable, even if the details are unclear. That is, we think we can successfully model the world in terms of fields that obey the rules of quantum mechanics, evolving within a curved spacetime obeying the laws of general relativity. The value 10^{-43} seconds is the "Planck time," before which we expect spacetime itself to be subject to quantum behavior. Currently we don't have a reliable theory that describes gravity in quantum-mechanical terms; the search for a theory of "quantum gravity" is one of the foremost goals of modern physics. The leading candidate for such a synthesis, string theory, has been the subject of an enormous amount of attention in recent decades. Unfortunately, despite a number of intriguing theoretical discoveries, string theory has neither made direct contact with experiments, nor provided an unambiguous answer to what happened at the Big Bang.

One sometimes hears the claim that the Big Bang was the beginning of both time and space; that to ask about spacetime "before the Big Bang" is like asking about land "north of the North Pole." This may turn out to be true, but it is not an established understanding. The singularity at the Big Bang doesn't indicate a beginning to the universe, only an end to our theoretical comprehension. It may be that this moment does indeed correspond to a beginning, and a complete theory of quantum gravity will eventually explain how the universe started at approximately this time. But it is equally plausible that what we think of as the Big Bang is merely a phase in the history of the universe, which stretches long before that time – perhaps infinitely far in the past. The present state of the art is simply insufficient to decide between these alternatives; to do so, we will need to formulate and test a working theory of quantum gravity.

Theories of Creation

The inability of established physics to describe the Big Bang event makes it tempting to consider the possibility that God has a crucial role to play at this unique moment in the history of the universe. If we were able to construct a complete and compelling naturalistic account, the necessity of appealing to God would be diminished. A number of avenues toward this goal are being explored. They can be divided into two types: "beginning" cosmologies, in which there is a first moment of time, and "eternal" cosmologies, where time stretches to the past without limit.

There are a number of avenues currently being explored by physicists that hope to provide a complete and self-contained account of the universe, including the Big Bang. Roughly speaking they can be divided into two types: "beginning" cosmologies, in which there is a first moment of time, and "eternal" cosmologies, where time stretches to the past without limit.

"Beginning" cosmologies typically attempt to replace the Big Bang singularity of classical general relativity with some sort of quantum-mechanical event, and often go by the name "quantum cosmology" (Hartle and Hawking 1983, Vilenkin 1984). These models imagine that spacetime is a classical approximation to some sort of quantum-mechanical structure. (Even if we don't have a complete theory of quantum gravity, the hope is that the basic features of quantum mechanics and general relativity are sufficiently robust that the details aren't important for this particular question.) In particular, *time* may be just an approximate notion, useful in some regimes but not others. Near the Big Bang is an obvious candidate for an era in which time loses its conventional meaning. The important ingredient is then a "boundary condition" that describes the state of the universe at the moment when time is first an intelligible concept. The most famous example is the "no-boundary proposal" of Hartle and Hawking, which constructs the state of the universe by integrating over all possible Euclidean geometries with no other boundaries. By "Euclidean" we mean geometries in which all four dimensions are spatial, in contrast to the "Lorentzian" geometry of spacetime with its distinction between timelike and spacelike directions. One occasionally speaks of "imaginary time," a phrase that has probably not increased the total amount of understanding in the universe.

A provocative way of characterizing these beginning cosmologies is to say that "the universe was created from nothing." Much debate has gone into deciding what this claim is supposed to mean. Unfortunately, it is a fairly misleading natural-language translation of a concept that is not completely well-defined even at the technical level. Terms that are imprecisely defined include "universe," "created," "from," and "nothing." (We can argue about "was.")

The problem with "creation from nothing" is that it conjures an image of a pre-existing "nothingness" out of which the universe spontaneously appeared – not at all what is actually involved in this idea. Partly this is because, as human beings embedded in a universe with an arrow of time, we can't help but try to explain events in terms of earlier events, even when the event we are trying to explain is explicitly stated to be the earliest one. It would be more accurate to characterize these models by saying "there was a time such that there was no earlier time."

To make sense of this, it is helpful to think of the present state of the universe and work backwards, rather than succumbing to the temptation to place our imaginations "before" the universe came into being. The beginning cosmologies posit that our mental journey backwards in time will ultimately reach a point past which the concept of "time" is no longer applicable. Alternatively, imagine a universe that collapsed into a Big Crunch, so that there would be a future end point to time. We aren't tempted to say that such a universe "transformed into nothing"; it simply has a final moment of its existence. What

actually happens at such a boundary point depends, of course, on the correct quantum theory of gravity.

The important point is that we can easily imagine self-contained descriptions of the universe that have an earliest moment of time. There is no logical or metaphysical obstacle to completing the conventional temporal history of the universe by including an atemporal boundary condition at the beginning. Together with the successful post-Big-Bang cosmological model already in our possession, that would constitute a consistent and self-contained description of the history of the universe.

Nothing in the fact that there is a first moment of time, in other words, necessitates that an external something is required to bring the universe about at that moment. As Hawking (1988, 156) put it in a celebrated passage:

> So long as the universe had a beginning, we could suppose it had a creator. But if the universe is really self-contained, having no boundary or edge, it would have neither beginning nor end, it would simply be. What place, then, for a creator?

The issue of whether or not there actually is a beginning to time remains open. Even though classical general relativity predicts a singularity at the Big Bang, it's completely possible that a fully operational theory of quantum gravity will replace the singularity by a transitional stage in an eternal universe. A variety of approaches along these lines are being pursued by physicists: bouncing cosmologies in which a single Big Crunch evolves directly into our observed Big Bang (Gasperini and Veneziano 1993; Bojowald 2001; Khoury et al. 2001), cyclic cosmologies in which there are an infinite number of epochs separated by Big Bangs (Steinhardt and Turok 2002; Penrose 2001), and baby-universe scenarios in which our Big Bang arises spontaneously out of quantum fluctuations in an otherwise quiet spacetime (Farhi et al. 1990; Fischler et al. 1990; Carroll and Chen 2004). There is no way to decide between beginning and eternal cosmologies on the basis of pure thought; both possibilities are being actively pursued by working cosmologists, and a definitive judgment will have to wait until one or the other approach develops into a mature scientific theory that makes contact with observations.

Interestingly, many (although certainly not all) natural theologians have managed to resist the temptation to point to the Big Bang as evidence of God's existence. Since the Fourth Lateran Council declared that the universe had a beginning in time and was created by God *ex nihilo*, the Big Bang would seem to fit relatively naturally into Christian theology. One figure who gave into temptation was Pope Pius XII, who in 1951 argued:

> In fact, it would seem that present-day science, with one sweeping step back across millions of centuries, has succeeded in bearing witness to that primordial *Fiat Lux* uttered at the moment when, along with matter, there burst forth from nothing a sea of light and radiation, while the particles of chemical elements split and formed into million of galaxies… Therefore, there is a Creator. Therefore, God exists! (quoted in Singh 2005, 360)

However, one figure who famously did not take that route was Georges Lemaître, the Belgian priest and physicist who in the 1920's developed the original Big Bang model (which he called the "primeval atom"). Lemaître resolutely declined to draw any theological conclusions from his theory, preferring to keep his religious beliefs strictly separate from his scientific work (Lemaître 1958, 1). He later served as a member of the Pontifical Academy of Sciences, and advised Pius against using scientific discoveries as evidence in theological arguments.

Why This Universe?

In recent years, a different aspect of our universe has been seized upon by natural theologians as evidence for God's handiwork – the purported fine-tuning of the physical and cosmological parameters that specify our particular universe among all possible ones. These parameters are to be found in the laws of physics (the mass of the electron, the value of the vacuum energy) as well as in the history of the universe (the amount of dark matter, the smoothness of the initial state). There's no question that the universe around us would look very different if some of these parameters were changed (Rees 1999). The controversial claims are two: that intelligent life can only exist for a very small range of parameters, in which our universe just happens to find itself; and that the best explanation for this happy circumstance is that God arranged it that way.

The clearest example of apparent fine-tuning is the vacuum energy (Carroll 2001). As discussed above, vacuum energy is the leading candidate for the dark energy causing distant galaxies to accelerate; but even if the vacuum energy is exactly zero and the dark energy is something else, we can safely say that the value of the vacuum energy is not greater than that of the dark energy, about 10^{-8} ergs per cubic centimeter. Using techniques from quantum field theory, we can do a rough calculation of what we would expect the vacuum energy to be, if we hadn't already measured it. The answer is quite a bit larger: about 10^{112} ergs per cubic centimeter. The fact that the actual value of the vacuum energy is at least 120 orders of magnitude smaller than its natural value is a fine-tuning by anyone's estimation.

Cosmologists don't have a compelling model for why the vacuum energy is so much smaller than it should be. But if it were anywhere near its "natural" value, we would not be here talking about it. Vacuum energy pulls objects away from each other, and a value much larger than what is observed would prohibit galaxies and stars from forming, presumably making it harder for life to exist.

Other constants of nature, such as those that govern atomic and nuclear physics, seem natural by themselves, but would give rise to very different macroscopic phenomena if they were changed even slightly. For example, if the mass of the neutron were a bit larger (in comparison to the mass of the proton) than its actual value, hydrogen would not fuse into deuterium and conventional stars would be impossible; if the neutron mass were a bit smaller, all the hydrogen in the early universe would fuse into helium, and helium stars in the late universe would have much shorter lifetimes (Hogan 2000; Collins 2003). (On the other hand, Adams has argued that a wide range of physical parameters leads to stars sustained by nuclear fusion (Adams 2008).)

In the face of these apparent fine-tunings, we have several possible options:

1. Life is extremely robust, and would be likely to arise even if the parameters were very different, whether or not we understand what form it would take.
2. There is only one universe, with randomly-chosen parameters, and we just got lucky that they are among the rare values that allow for the existence of life.
3. In different regions of the universe the parameters take on different values, and we are fooled by a selection effect: life will only arise in those regions compatible with the existence of life.
4. The parameters are not chosen randomly, but designed that way by a deity.

Generally, not nearly enough credence is given to option #1 in this list. We know very little about the conditions under which complexity, and intelligent life in particular, can possibly form. If, for example, we were handed the Standard Model of particle physics but

had no actual knowledge of the real world, it would be very difficult to derive the periodic table of the elements, much less the atoms and molecules on which Earth-based life depends. Life may be very fragile, but for all we know it may be ubiquitous (in parameter space); we have a great deal of trouble even defining "life" or for that matter "complexity," not to mention "intelligence." At the least, the tentative nature of our current understanding of these issues should make us reluctant to draw grand conclusions about the nature of reality from the fact that our universe allows for the existence of life.

Nevertheless, for the sake of playing along, let's imagine that intelligent life only arises under a very restrictive set of circumstances. Following Swinburne (1990), we can cast the remaining choices in terms of Bayesian probability. The basic idea is simple: we assign some prior probability – before we take into account what we actually know about the universe – to each of the three remaining scenarios. Then we multiply that prior probability by the probability that intelligent life would arise in that particular model. The result is proportional to the probability that the model is correct, given that intelligent life exists.[2] Thus, for option #2 (a single universe, no supernatural intervention), we might put the prior probability at a relatively high value by virtue of its simplicity, but the probability of life arising (we are imagining) is extremely small, so much so that this model could be considered unlikely in comparison with the other two.

We are left with option #3, a "multiverse" with different conditions in different regions (traditionally called "universes" even if they are spatially connected), and #4, a single universe with parameters chosen by God to allow for the eventual appearance of life. In either case we can make a plausible argument that the probability of life arising is considerable. All of the heavy lifting, therefore, comes down to our prior probabilities – our judgments about how *a priori* likely such a cosmological scenario is. Sadly, prior probabilities are notoriously contentious objects.

I will consider more carefully the status of the "God hypothesis," and its corresponding prior probability, in the final section. For now, let's take a look at the multiverse.

The Multiverse and Fine-Tuning

There are (at least) two popular mechanisms to obtain a multiverse. One is the many-worlds or Everett interpretation of quantum mechanics; I won't discuss this idea here, because the various "branches of the wave function" describing different worlds all share the same basic laws of physics. The other kind of multiverse is in some sense more prosaic, in that it simply posits regions of spacetime outside our observable horizon, in which conditions are very different – including, in principle and often in practice, the parameters specifying the laws of physics, such as the mass of the neutron or the vacuum energy.

This latter scenario has garnered a great deal of attention in recent years, in part because it seems to be a natural outcome of two powerful ideas that were originally pursued for other reasons: inflationary cosmology, and superstring theory. Inflation uses the fact that dark energy makes the universe accelerate, but posits an initially small region of space filled with a temporary form of super-dark-energy at an enormously high density. This causes this small region to grow to fantastic size, before the dark energy ultimately decays. In many versions of the theory, the decay isn't complete, and at least some region is always undergoing ultra-fast inflationary expansion (Guth 1998). From string theory we get the idea of a "landscape" of possible vacuum states. A "vacuum state" is simply a configuration of empty space with an associated set of physical laws. That is, what we think of as spacetime comes in a variety of phases, much like water can be in solid, liquid, or gaseous forms. In string theory there seems to be a mind-boggling number of possible

phases (over 10^{500}), each characterized by different physical constants, including the set of elementary particles and the number of macroscopic dimensions of space (Vilenkin 2007; Susskind 2006; Greene 2011).

The multiverse comes to life by combining inflation with string theory. Once inflation starts, it produces a limitless supply of different "pocket universes," each in one of the possible phases in the landscape of vacuum states of string theory. Given the number of potential universes, it wouldn't be surprising that one (or an infinite number) were compatible with the existence of intelligent life. Once this background is in place, the "anthropic principle" is simply the statement that our observable universe has no reason to be representative of the larger whole: we will inevitably find ourselves in a region that allows for us to exist.

What prior likelihood should we assign to such a scenario? One popular objection to the multiverse is that it is highly non-parsimonious; is it really worth invoking an enormous number of universes just to account for a few physical parameters? As Swinburne (1996, 68) says:

> To postulate a trillion trillion other universes, rather than one God in order to explain the orderliness of our universe, seems the height of irrationality.

That might be true, even with the hyperbole, if what one was postulating were simply "a trillion trillion other universes." But that is a mischaracterization of what is involved. What one postulates are not universes, but laws of physics. Given inflation and the string theory landscape (or other equivalent dynamical mechanisms), a multiverse happens, whether you like it or not.

This is an important point that bears emphasizing. All else being equal, a simpler scientific theory is preferred over a more complicated one. But how do we judge simplicity? It certainly doesn't mean "the sets involved in the mathematical description of the theory contain the smallest possible number of elements." In the Newtonian clockwork universe, every cubic centimeter contains an infinite number of points, and space contains an infinite number of cubic centimeters, all of which persist for an infinite number of separate moments each second, over an infinite number of seconds. Nobody ever claimed that all these infinities were a strike against the theory. Indeed, in an open universe described by general relativity, space extends infinitely far, and lasts infinitely long into the future; again, these features are not typically seen as fatal flaws. It is only when space extends without limit and conditions change from place to place, representing separate "universes," that people grow uncomfortable. In quantum mechanics, any particular system is potentially described by an infinite number of distinct wave functions; again, it is only when different branches of such a wave function are labeled as "universes" that one starts to hear objections, even if the mathematical description of the wave function itself hasn't grown any more complicated.

A scientific theory consists of some formal structure, as well as an "interpretation" that matches that structure onto the world we observe. The structure is a statement about patterns that are exhibited among the various objects in the theory. The simplicity of a theory is a statement about how compactly we can describe the formal structure (the Kolmogorov complexity), not how many elements it contains. The set of real numbers consisting of "eleven, and thirteen times the square root of two, and pi to the twenty-eighth power, and all prime numbers between 4,982 and 34,950" is a more complicated set than "the integers," even though the latter set contains an infinitely larger number of elements. The physics of a universe containing 10^{88} particles that all belong to just a handful of types, each particle behaving precisely according to the characteristics of its type, is much simpler

than that of a universe containing only a thousand particles, each behaving completely differently.

Likewise, a multiverse that arises due to the natural dynamical consequences of a relatively simple set of physical laws should not be discounted because there are a lot of universes out there. Multiverse theories certainly pose formidable problems, especially when it comes to making predictions and comparing them with data; for that reason, most scientists would doubtless prefer a theory that directly predicted the parameters we observe in nature over a multiverse ensemble in which our local environment was explained anthropically. But most scientists (for similar reasons) would prefer a theory that was completely free of appeals to supernatural agents.

The multiverse is not a theory; it is a prediction of a theory, namely the combination of inflationary cosmology and a landscape of vacuum states. Both of these ideas came about for other reasons, having nothing to do with the multiverse. If they are right, they predict the existence of a multiverse in a wide variety of circumstances. It's our job to take the predictions of our theories seriously, not to discount them because we end up with an uncomfortably large number of universes.

The multiverse, by itself, doesn't offer an explanation for every cosmological fine-tuning problem. If a parameter needs to be smaller than a certain value for life to exist, there's no anthropic reason for it to be *much* smaller than that value. We therefore have a prediction: anthropically-selected parameters should be of the same order of magnitude as the largest value compatible with the existence of life. Indeed, this prediction was successfully made by Steven Weinberg for the vacuum energy, over a decade before it was actually discovered (Weinberg 1987).

An example of fine-tuning well beyond anthropic constraints is the initial state of the universe, often characterized in terms of its extremely low entropy (Penrose 1989). Roughly speaking, the large number of particles in the universe were arranged in an extraordinarily smooth configuration, which is highly unstable and unlikely given the enormous gravitational forces acting on such densely-packed matter. While vacuum energy is tuned to one part in 10^{120}, the entropy of the early universe is tuned to one part in *ten to the power of* 10^{120}, a preposterous number. The entropy didn't need to be nearly that low in order for life to come into existence. One way of thinking about this is to note that we certainly don't need a hundred billion other galaxies in the universe in order for life to arise here on Earth; our single galaxy would have been fine, or for that matter a single solar system.

That doesn't mean that we can't possibly explain the low entropy of our early universe by invoking the multiverse; it just means that the explanation must rely on detailed dynamical properties of the multiverse, rather than simply the requirement that life can exist. What we would need to show is that, in the context of the particular multiverse scenario under consideration, when life arises at all it typically does so in the aftermath of an extremely low-entropy event like our Big Bang. This is a challenge, but not obviously an insuperable one, and researchers are actively tackling this question (Carroll 2010).

If anything, the much-more-than-anthropic tuning that characterizes the entropy of the universe is a bigger problem for the God hypothesis than for the multiverse. If the point of arranging the universe was to set the stage for the eventual evolution of intelligent life, why all the grandiose excess represented by the needlessly low entropy at early times and the universe's hundred billion galaxies? We might wonder whether those other galaxies are spandrels – not necessary for life here on Earth, but nevertheless a side effect of the general Big Bang picture, which is the most straightforward way to make the Earth and its biosphere. This turns out not to be true; quantitatively, it's easy to show that almost all

possible histories of the universe that involve Earth as we know it don't have any other galaxies at all.[3] It's unclear why God would do so much more fine-tuning of the state of the universe than seems to have been necessary.

Accounting for the World

So far we've been discussing roles for God that match those of a conventional scientific theory – providing a clear and compelling account of the observational facts. There is another angle often taken by natural theologians in explaining God's usefulness to cosmology: that, whatever the facts of the world might be and whatever patterns they might follow, only a divine being can offer a "reason why" things are that way, over and above the facts and patterns themselves.

This approach takes a number of different forms. One is to give God credit for simply allowing the universe to exist:

> For Judeo-Christianity, God is not a person in the sense that Al Gore arguably is… He is, rather, the condition of possibility of any entity whatsoever, including ourselves. He is the answer to why there is something rather than nothing. (Eagleton 2006, 32)

Another is to sustain the existence of the universe. In response to Hawking's question "What place, then, for a creator?", John Polkinghorne (1994, 73) answers:

> [I]t would be theologically naïve to give any answer other than: "Every place – as the sustainer of the self-sustained spacetime egg and as the creator of its quantum laws."

Along similar lines, God is sometimes credited with maintaining the regularities observed in nature, which would otherwise simply be a coincidence.

> The same laws of nature govern the most distant galaxies we can observe through our telescopes as operate on earth, and the same laws govern the earliest events in time to which we can infer as operate today… If there is no cause of this, it would be a most extraordinary coincidence – too extraordinary for any rational person to believe. (Swinburne 1996, 49)

A final example comes from the traditional "cosmological" arguments for God's existence. In the "*Kalam*" formulation championed by William Lane Craig (1979), the first premise of the argument states "everything that has a beginning in time has a cause." Things cannot simply begin; something must begin them.

For convenience I am brutally lumping together quite different arguments, but hopefully the underlying point of similarity is clear. These ideas all arise from a conviction that, in various contexts, it is insufficient to fully understand what happens; we must also provide an explanation for *why* it happens – what might be called a "meta-explanatory" account.

It can be difficult to respond to this kind of argument. Not because the arguments are especially persuasive, but because the ultimate answer to "We need to understand why the universe exists/continues to exist/exhibits regularities/came to be" is essentially "No we don't." That is unlikely to be considered a worthwhile comeback to anyone who was persuaded by the need for a meta-explanatory understanding in the first place.

Granted, it is always nice to be able to provide reasons why something is the case. Most scientists, however, suspect that the search for ultimate explanations eventually terminates in some final theory of the world, along with the phrase "and that's just how it is." It is certainly conceivable that the ultimate explanation is to be found in God; but a compelling argument to that effect would consist of a demonstration that God provides a better explanation (for whatever reason) than a purely materialist picture, not an *a priori* insistence that a purely materialist picture is unsatisfying.

Why are some people so convinced of the need for a meta-explanatory account, while others are perfectly happy without one? I would suggest that the impetus to provide such an account comes from our experiences within the world, while the suspicion that there is no need comes from treating the entire universe as something unique, something for which a different set of standards is appropriate.

For example, we could imagine arguing that there is no puzzle associated with the value of the vacuum energy. It had to be some number, and we have (perhaps) measured what that value is, and there's nothing more to be said. (Some physicists, although a minority, do hold this view, and similarly for other fine-tuning problems.) The counter-argument is that the vacuum energy is really a parameter that we measure in the "effective field theory" that governs physics at low energies, regardless of the virtual high-energy processes we have not yet explored in experiments. Even though there is only one universe, there are many effective field theories, and many parameters in the theories relevant to low-energy physics. So the vacuum energy is not a unique object; we have expectations for it based on our experience with other parameters in effective field theories, and can sensibly compare its measured value to those expectations. It is in terms of that comparison that we can legitimately call the vacuum energy finely-tuned.

States of affairs only require an explanation if we have some contrary expectation, some reason to be surprised that they hold. Is there any reason to be surprised that the universe exists, continues to exist, or exhibits regularities? When it comes to the universe, we don't have any broader context in which to develop expectations. As far as we know, it may simply exist and evolve according to the laws of physics. If we knew that it was one element of a large ensemble of universes, we might have reason to think otherwise, but we don't. (I'm using "universe" here to mean the totality of existence, so what would be called the "multiverse" if that's what we lived in.)

In Aristotle's *Metaphysics*, he suggested the need for an "unmoved mover" to explain the motion of ordinary objects. That makes sense in the context of Aristotle's physics, which was fundamentally teleological: objects tended toward their natural place, which is where they wanted to stay. How, then, to account for all the motion we find everywhere around us? But subsequent developments in physics – conservation of momentum, Newton's laws of motion – changed the context in which such a question might be asked. Now we know that objects that are moving freely continue to move along a uniform trajectory, without anything moving them. Why? Because that's what objects do. It's often convenient, in the context of everyday life, for us to refer to this or that event as having some particular cause. But this is just shorthand for what's really going on, namely: things are obeying the laws of physics.

Likewise for the universe. There is no reason, within anything we currently understand about the ultimate structure of reality, to think of the existence and persistence and regularity of the universe as things that require external explanation. Indeed, for most scientists, adding on another layer of metaphysical structure in order to purportedly explain these nomological facts is an unnecessary complication. This brings us to the status of God as a scientific hypothesis.

God as a Theory

Religion serves many purposes other than explaining the natural world. Someone who grew up as an altar server, volunteers for their church charity, and has witnessed dozens of weddings and funerals of friends and family might not be overly interested in whether God is the best explanation for the value of the mass of the electron. The idea of God has functions other than those of a scientific hypothesis.

However, accounting for the natural world is certainly a traditional role for God, and arguably a foundational one. How we think about other religious practices depends upon whether our understanding of the world around us gives us a reason to believe in God. And insofar as it attempts to provide an explanation for empirical phenomena, the God hypothesis should be judged by the standards of any other scientific theory.

Consider a hypothetical world in which science had developed to something like its current state of progress, but nobody had yet thought of God. It seems unlikely that an imaginative thinker in this world, upon proposing God as a solution to various cosmological puzzles, would be met with enthusiasm. All else being equal, science prefers its theories to be precise, predictive, and minimal – requiring the smallest possible amount of theoretical overhead. The God hypothesis is none of these. Indeed, in our actual world, God is essentially never invoked in scientific discussions. You can scour the tables of contents in major physics journals, or titles of seminars and colloquia in physics departments and conferences, looking in vain for any mention of possible supernatural intervention into the workings of the world.

At first glance, the God hypothesis seems simple and precise – an omnipotent, omniscient, and omnibenevolent being. (There are other definitions, but they are usually comparably terse.) The apparent simplicity is somewhat misleading, however. In comparison to a purely naturalistic model, we're not simply adding a new element to an existing ontology (like a new field or particle), or even replacing one ontology with a more effective one at a similar level of complexity (like general relativity replacing Newtonian spacetime, or quantum mechanics replacing classical mechanics). We're adding an entirely new metaphysical category, whose relation to the observable world is unclear. This doesn't automatically disqualify God from consideration as a scientific theory, but it implies that, all else being equal, a purely naturalistic model will be preferred on the grounds of simplicity.

There is an inevitable tension between any attempt to invoke God as a scientifically effective explanation of the workings of the universe, and the religious presumption that God is a kind of *person*, not just an abstract principle. God's personhood is characterized by an essential unpredictability and the freedom to make choices. These are not qualities that one looks for in a good scientific theory. On the contrary, successful theories are characterized by clear foundations and unambiguous consequences. We could imagine boiling God's role in setting up the world down to a few simple principles (*e.g.*, "God constructs the universe in the simplest possible way consistent with the eventual appearance of human beings"). But is what remains recognizable as God?

Similarly, the apparent precision of the God hypothesis evaporates when it comes to connecting to the messy workings of reality. To put it crudely, God is not described in equations, as are other theories of fundamental physics. Consequently, it is difficult or impossible to make predictions. Instead, one looks at what has already been discovered, and agrees that that's the way God would have done it. Theistic evolutionists argue that God uses natural selection to develop life on Earth; but religious thinkers before Darwin were unable to predict that such a mechanism would be God's preferred choice.

Ambitious approaches to contemporary cosmological questions, such as quantum cosmology, the multiverse, and the anthropic principle, have not yet been developed into mature scientific theories. But the advocates of these schemes are working hard to derive

testable predictions on the basis of their ideas: for the amplitude of cosmological perturbations (Hartle, Hawking, and Hertog 2008), signals of colliding pocket universes in the cosmic microwave background (Aguirre and Johnson 2009), and the mass of the Higgs boson and other particles (Feldstein et al. 2006). For the God hypothesis, it is unclear where one would start. Why does God favor three generations of elementary particles, with a wide spectrum of masses? Would God use supersymmetry or strong dynamics to stabilize the hierarchy between the weak scale and the Planck scale, or simply set it that way by hand? What would God's favorite dark matter particle be?

This is a venerable problem, reaching far beyond natural theology. In numerous ways, the world around us is more like what we would expect from a dysteleological set of uncaring laws of nature than from a higher power with an interest in our welfare. As another thought experiment, imagine a hypothetical world in which there was no evil, people were invariably kind, fewer natural disasters occurred, and virtue was always rewarded. Would inhabitants of that world consider these features to be evidence *against* the existence of God? If not, why don't we consider the contrary conditions to be such evidence?

Over the past five hundred years, the progress of science has worked to strip away God's roles in the world. He isn't needed to keep things moving, or to develop the complexity of living creatures, or to account for the existence of the universe. Perhaps the greatest triumph of the scientific revolution has been in the realm of methodology. Control groups, double-blind experiments, an insistence on precise and testable predictions – a suite of techniques constructed to guard against the very human tendency to see things that aren't there. There is no control group for the universe, but in our attempts to explain it we should aim for a similar level of rigor. If and when cosmologists develop a successful scientific understanding of the origin of the universe, we will be left with a picture in which there is no place for God to act – if he does (*e.g.*, through subtle influences on quantum-mechanical transitions or the progress of evolution), it is only in ways that are unnecessary and imperceptible. We can't be sure that a fully naturalist understanding of cosmology is forthcoming, but at the same time there is no reason to doubt it. Two thousand years ago, it was perfectly reasonable to invoke God as an explanation for natural phenomena; now, we can do much better.

None of this amounts to a "proof" that God doesn't exist, of course. Such a proof is not forthcoming; science isn't in the business of proving things. Rather, science judges the merits of competing models in terms of their simplicity, clarity, comprehensiveness, and fit to the data. Unsuccessful theories are never disproven, as we can always concoct elaborate schemes to save the phenomena; they just fade away as better theories gain acceptance. Attempting to explain the natural world by appealing to God is, by scientific standards, not a very successful theory. The fact that we humans have been able to understand so much about how the natural world works, in our incredibly limited region of space over a remarkably short period of time, is a triumph of the human spirit, one in which we can all be justifiably proud.

SEAN CARROLL

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[1] See also Carroll 2005, 62. For a different view, see chapters in this volume by Don Page, Robin Collins, and Steve Barr.

[2] It's not obvious that this line reasoning is valid. One could certainly imagine taking the position that our existence offers exactly zero information about the probability of any cosmological scenario, because if we didn't exist we wouldn't be here debating the alternatives. But for the moment we are playing along.

[3] Given laws of motion, the space of histories of the universe is isomorphic to the space of states at some fixed time. The entropy is the logarithm of the number of macroscopically similar states. The fact that we can imagine much higher-entropy configurations of the universe today without disturbing the Earth (*e.g.*, by putting the rest of the universe into black holes) demonstrates that histories like ours are an incredibly tiny fraction of histories that give rise to something like our current Earth.